COMPUTATIONS OF BOILING IN MICROGRAVITY

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Proposed Research

- Development of a three-dimensional, grid adaptive, fully parallel numerical method and a code to simulate boiling in microgravity. The method is based on an already existing two-dimensional code and techniques used for three-dimensional flows with no phase change
- The applications of the method to study the growth of bubbles in boiling heat transfer under both flow and no-flow conditions as well as the resulting heat transfer

Numerical Method

Finite Difference/Front Tracking discretization of the "one-field" formulation.
Source terms are added at the interface to satisfy boundary conditions there.

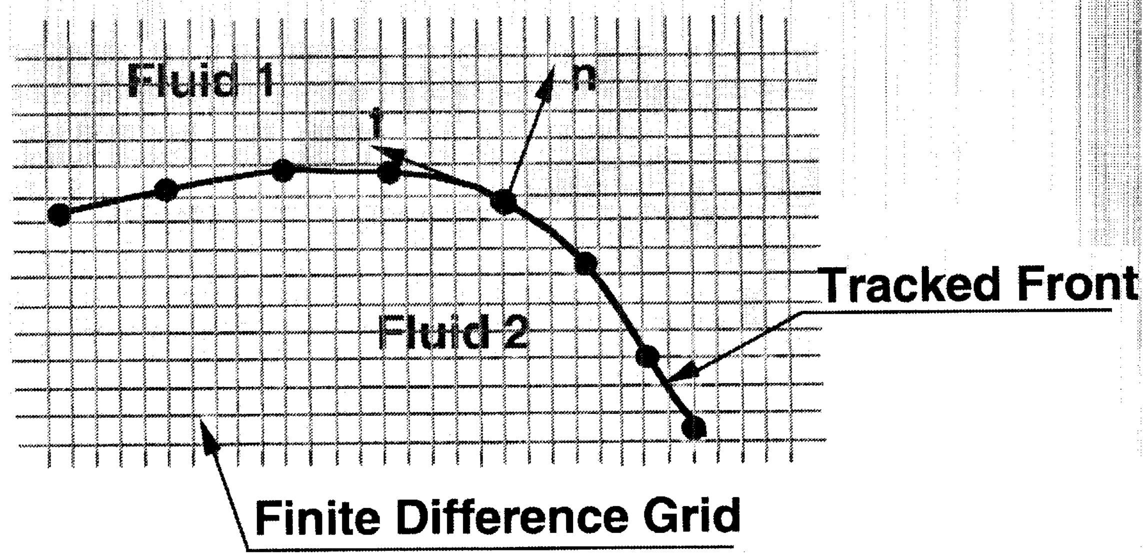
$$\frac{\partial \rho \bar{u}}{\partial t} + \nabla \cdot \rho \bar{u}\bar{u} = -\nabla p + \bar{f} + \nabla \cdot \mu\left(\nabla \bar{u} + \nabla^T \bar{u}\right) + \int_F \sigma \kappa \bar{n} \delta\left(\bar{x} - \bar{x}_f\right) da$$

$$\nabla \cdot \bar{u} = 0$$

$$\frac{D\rho}{Dt} = 0$$

$$\frac{D\mu}{Dt} = 0$$

Second order time and space discretization on a staggered grid

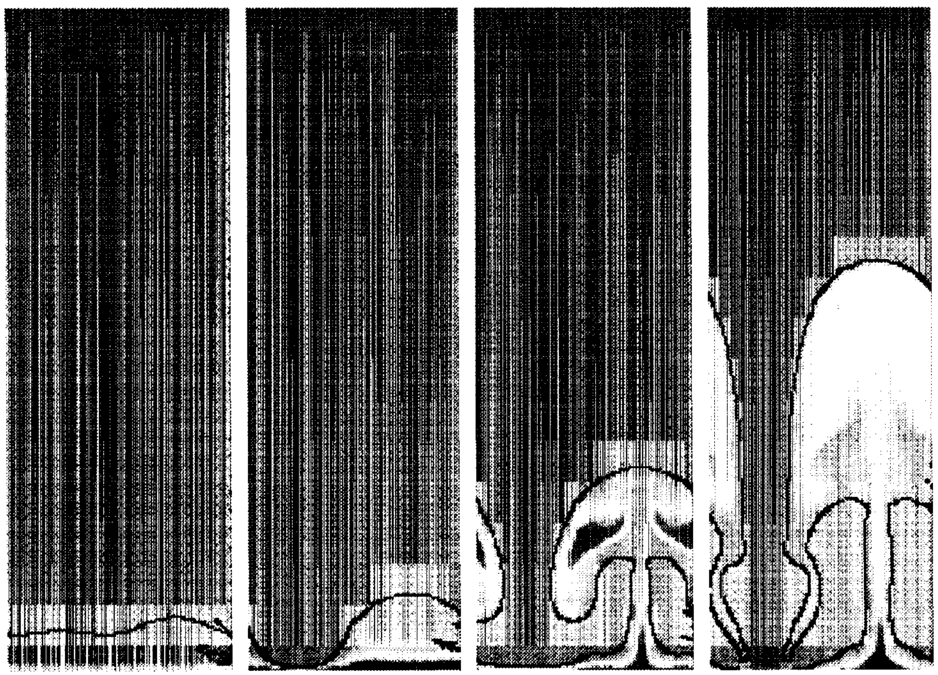


References:

S.O. Unverdi and G. Tryggvason. A front-tracking method for viscous, incompressible, multi-fluid flows, J. Comput Phys. 100 (1992), 25-37

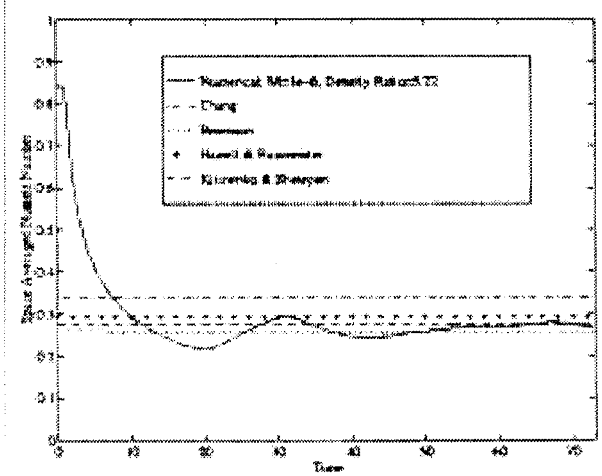
D. Juric and G. Tryggvason. Computations of Boiling Flows. To appear in Int'l. J. Multiphase Flow.

Preliminary Results-Boiling



Two-dimensional results

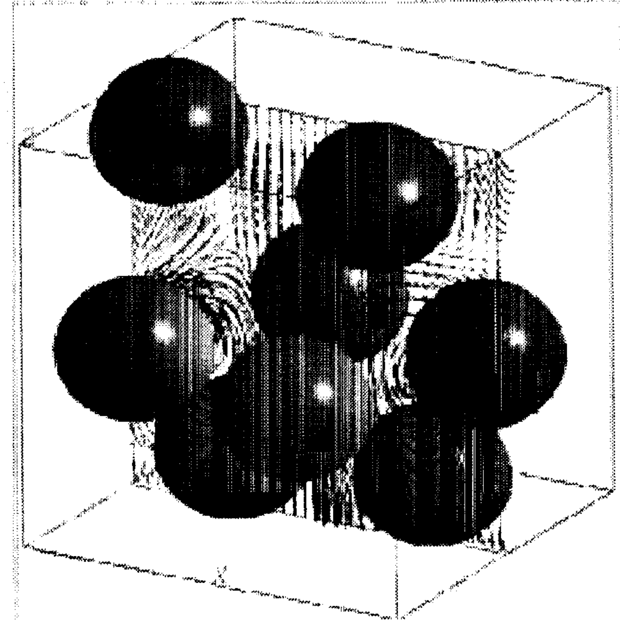
Reference: D. Juric and G. Tryggvason. Computations of Boiling Flows. To appear in Int'l. J. Multiphase Flow.



The boiling of hydrogen at high pressure is shown in the figure above, at four different times. The color represents the temperature, with red hot and blue cold. The bottom wall has a constant heat flux. The average heat flux is shown versus time in the figure to the right. Prediction by various experimental correlations are shown by horizontal lines.

Other Relevant Results

Dendritic Solidification



Motion of bubbles

Other Applications—A few examples:

M.R. Nobari, Y.-J. Jan and G. Tryggvason. "Head-on Collision of Drops--A Numerical Investigation." Phys. Fluids 8, 29-42 (1996).

M.R.H. Nobari, and G. Tryggvason, "Numerical Simulations of Three-Dimensional Drop Collisions." AIAA Journal 34 (1996), 750-755.

A. Esmaeeli and G. Tryggvason, "An Inverse Energy Cascade in Two-Dimensional, Low Reynolds Number Bubbly Flows." J. Fluid Mech. 314 (1996), 315-330.

G. Agresar, J.J. Linderman, G. Tryggvason, and K.G. Powell. An Adaptive, Cartesian, Front-Tracking Method for the Motion, Deformation and Adhesion of Circulating Cells. To appear in J. Comput. Phys.

Conclusion

The physical problem addressed in this study is of fundamental importance for thermal/fluid management in microgravity. Since flow regimes are usually very different than on earth, design data obtained on earth is generally not applicable to microgravity conditions. This study will result in both a greatly improved understanding of boiling multiphase flows as well as tools that can be used to address other situations. This should greatly reduce the need for experiments for relatively simple situations and help plan experiments for more complex flows.